METHODS FOR ARTERIAL PRESSURIZATION OF THE HEAD

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The following is a description of the procedure used at the State University of New York at Buffalo in conjunction with the Calspan Corporation for the pressurization of the arterial system in lateral head impact studies.

I. Selection of a Subject

Because of the many problems encountered in pressurization of the arterial system, care should be taken when selecting a subject for the study. The following information is considered in selecting a subject for our studies: (1) age, (2) interval since time of death, (3) cause of death. (1) The age of a subject is important in that the older an individual, the greater the chance of osteoporosis. Furthermore, females over the age of 50 who have completed menopause likewise develop this disease and thus have a weakening of bone structure. (2) The interval since time of death should be considered do to the shrinkage of tissue. Upon death, tissues in the body begin to shrink; the brain is no exception. Normally the brain lies immediately adjacent to bones of the skull and therefore it is imperative to use a subject as soon as possible following death in order to keep this integrity. Correct findings on how an impact to the skull affect the brain rely on the integrity of this relationship. Naturally if the brain is separated from the skull by an abnormal distance, the results will not mimic the occurance seen under real-life conditions. (3) Finally, the cause of death is very important. Some diseases affect the bones as seen above while others may damage the vascular system. Diseases such as diabetes or atherosclerosis affect arteries and thus may cause problems in producing proper pressurization. One other consideration should also be mentioned and that is blood pressure. In a study in which the arterial blood pressure is monitored during an impact it is important to mimic the subjects normal blood pressure immediately before and after impact. We acquire from the subject's former physician the average normal blood pressure in order to reproduce this pressure during the experiment. Not everyone has a pressure of 120/80 or 110/70 and therefore if we are interested in whether or not there is a rupture of a cerebral vessel because of the impact it is important that we do not exceed the subject's normal pressure prior to the test. Perfusing to a pressure exceeding the subject's normal pressure may cause a premature rupture of a blood vessel thus producing a false result.

II. Isolating the Vessels Supplying the Brain

Proper pressurization of the brain requires that the major arteries supplying it are isolated and ligated. The brain is supplied by two major pairs of arteries; the internal carotids and vertebrals. In order to reduce the damage to surrounding tissues, the size of the incisions are kept to a minimum. The following procedure is performed bilaterally on a subject prior to an attempt at pressurization.

To isolate and ligate the vertebral arteries a 6cm incision is made overlying the medial part of the clavicle. The clavicular head of the pectoralis major and the subclavius muscles are reflected from the bone.

Upon reflecting the subclavian vein, the subclavian artery is ligated just lateral to the thyrocervical trunk bilaterally (Fig. 1). The incision is then closed using either suture or metal clips.

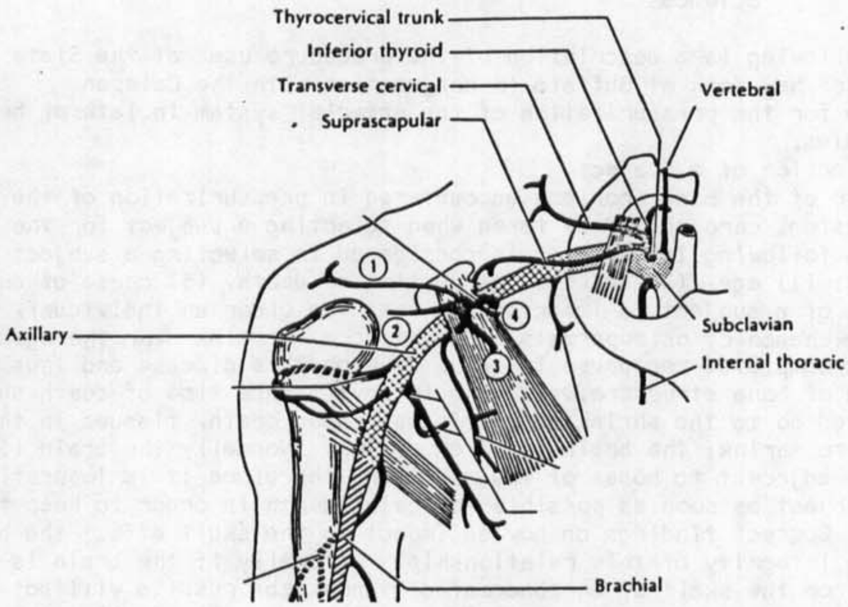


Figure 1. Position of thyrocervical trunk and vertebral artery exiting subclavian.

Next an exposure is made of the carotid and vertebral system in the neck. Two structures are palpated prior to making an incision the hyoid bone and sternocleidomastoid muscle. The hyoid bone lies at vertebral level C4. The common carotid artery bifurcates into an internal and external carotid artery at approximately this level and therefore to find this bifurcation more readily, the bone is used as a landmark (Fig. 2B). A 6cm incision is made bilaterally at this level through the skin paralleling the course of the sternocleidomastoid muscle (Fig. 2A). Care is taken to avoid damaging the external jugular vein which crosses the muscle. Once the muscle fibers are observed, an incision is made through the muscle parallel with its fibers and posterior to the contents of the carotid sheath. The sheath is opened and the internal jugular vein and vagus nerve reflected anteriorly. The common carotid and its bifurcation into an internal and external carotid are then isolated.

The common carotid is ligated at approximately vertebral level C6. The external carotid is subsequently ligated at its origin. A small incision is then made into the common carotid above its ligature to allow for the insertion of a pressurization tube. The tube is fed through the common into the internal carotid to a point 2cm below the base of the skull. The tube is then sutured into place. One important problem should be mentioned at this time. A narrowing of an artery especially the carotids, often occurs at a bifurcation site. By incising the common carotid one can just as easily pressurize using this artery if a narrowing is encountered when passing the tube toward the base of the skull. A total blockage at the bifurcation will of course prevent any pressurization of the brain. The above procedure is done bilaterally.

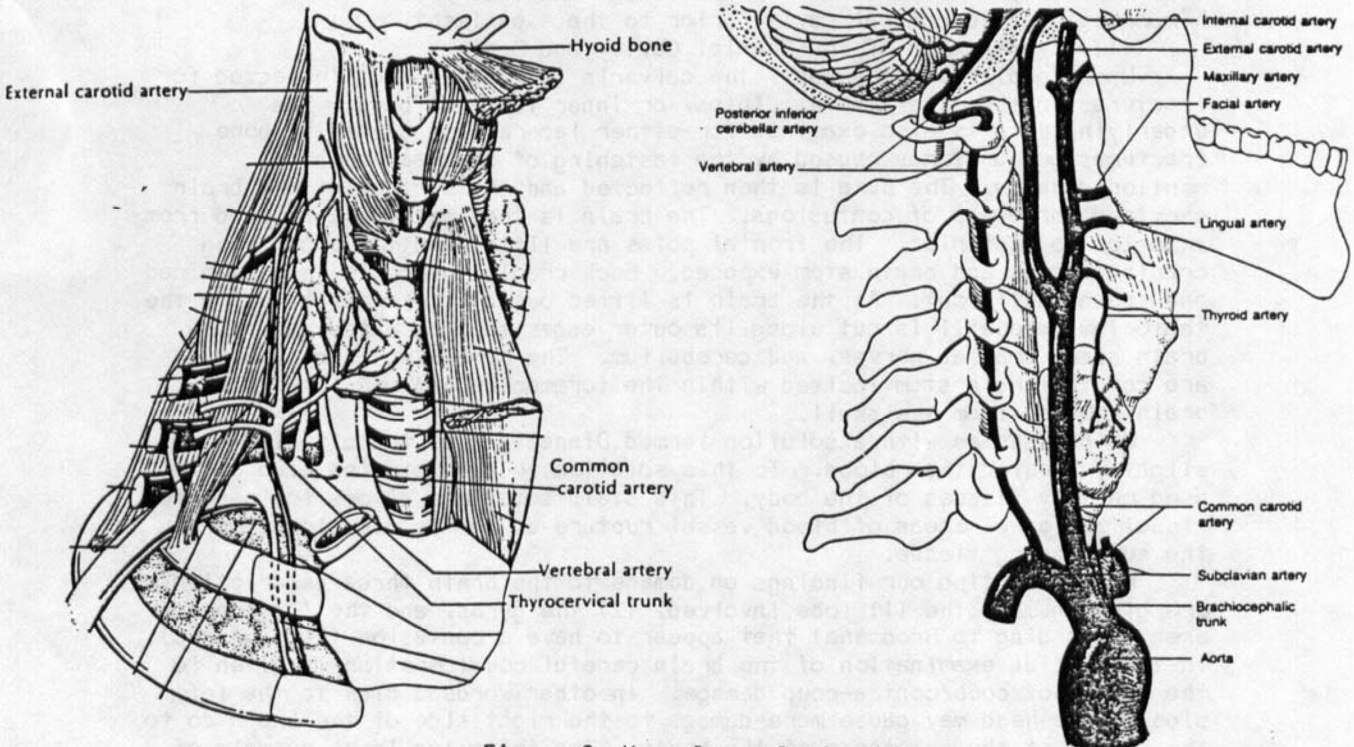


Figure 2. Vascular relationships in the neck.

Finally, the vertebral arteries are ligated. Upon exiting the subclavian and before entering the transverse foramina of the C6 vertebra the vertebral arteries are exposed for a short time in the scalene triangle at the base of the neck. It is in this location that the arteries may be isolated and ligated. The incision made to expose the carotids may also be used to approach the vertebrals. The cricoid cartilage is easily palpabable in the neck. Because it is located at C6 it serves as a landmark in finding the entery point of the vertebral artery into the transverse foramen of the vertebra. The artery is ligated immediately before entering the foramen (Fig. 2B). Upon completion of this procedure, the incision over the sternocleidomastoid is closed either by sutures or metal clips.

It should also be noted that at least 24 hours prior to a test the prevertebral muscles are injected with a 4% formalin solution. This is done to stiffen the muscles and thus mimic some muscle tone. Also a head mount with attached accelerometers is placed on the vertex of the skull prior to a test. In the placement of this mount, it is necessary to drill through the calvaria and then secure the mount with rivets. During the procedure of drilling through the skull it is important that the underlying dura and superior surface are not punctured. Puncturing of either of these structures may also puncture a blood vessel and thus produce some hemorrhage in the cranial cavity prior to the experiment.

III. Examination of the Cranial Cavity and Brain

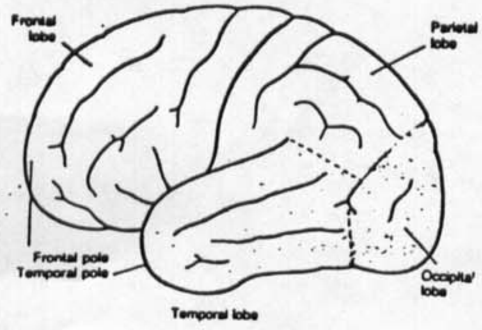
Upon completion of a test, the calvaria is removed and inspected for fractures in the outer table, diploe, or inner table of bone. The underlying dura is also examined for either lacerations caused by bone fractures or punctures caused by the fastening of the head mount as mentioned above. The dura is then reflected and the surface of the brain examined for areas of contusions. The brain is then carefully removed from anterior to posterior. The frontal poles are lifted and the underlying cranial nerves and brain stem exposed. Each cranial nerve is then examined and subsequently cut. As the brain is lifted out of the cranial cavity the tentorium cerebelli is cut along its outer edges to expose the remaining brain stem, cranial nerves, and cerebellum. The remaining cranial nerves are cut the brain stem incised within the foramen magnum and the entire brain removed from the skull.

We pressurize with a solution termed Dianeal. Its tonicity is slightly greater than blood. To this solution we add toludine blue a stain used on many tissues of the body. This stain sometimes allows for a better visualization of areas of blood vessel rupture do to its discoloration of the surrounding tissue.

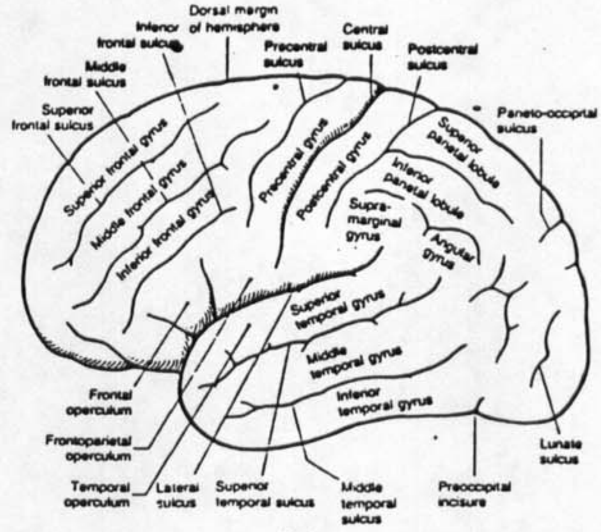
When reporting our findings on damage to the brain three descriptions are given namely the (1) lobe involved, (2) the gyrus, and the (3) precise area (according to Brodmann) that appear to have a contusion (Fig. 3A,B,C). In the initial examination of the brain careful consideration is given to the notion of coup/contra-coup damage. In other words a blow to the left side of the head may cause more damage to the right side of the brain do to the nature of the substance of the brain. The following is an example of how we would report our findings upon examination of a brain following a left lateral head impact test.

Calman 30 was a 66 year old male subjected to a left lateral head impact test. Upon examination of the brain, multiple contusions were observed in the caudal part of the frontal lobe and rostral part of the parietal lobe on the right side. In particular area 4 (precentral gyrus), areas 44 and 45 (gyrus triangularis and opercularis) and area 3,1,2 (postcentral gyrus) showed significant contusions.

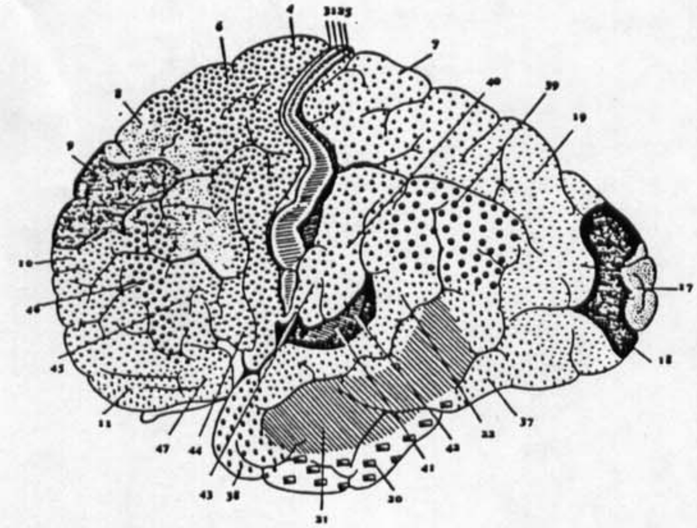
On the left side, contusions were observed throughout the frontal lobe as well as an isolated contusion in the superior part of the temporal lobe. In particular areas 6, 8, 10 (superior and middle frontal gyri) area 4 (precentral gyrus) and areas 44 and 45 (gyrus triangularis and opercularis) of the frontal lobe showed contusions. In the temporal lobe only area 22 (superior temporal gyrus) displayed damage.



(A)



(B)



(C)

Figure 3. Lateral views of brain showing the lobes (A), gyri and sulci (B), and areas according to Brodmann (C).

This type of description of the damage is given in all of our subjects. We can only suggest what type of permanent damage or deficit a living person may display. We know the function of each of the areas of the brain and therefore if they are permanently damaged we can predict what deficits a patient may sustain. For example damage to area 4 may produce a contralateral spastic hemiplegia. We are currently processing some of the brains to determine the depth of the damage. Once we know what layers of the cerebral cortex are involved we will be able to more accurately predict the extent of permanent damage and disability to a living individual.